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|  | **Technical Handbooks of FRM4VEG Instrumentation****(TR-1): Delta-T Devices BF3 Sunshine Sensor**version 1.0National Physical Laboratory University of SouthamptonEOLAB28 May 2020  |
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##### Acronyms

|  |  |
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| **Abbreviation** | **Stands For** |
| CMOS | Complementary metal-oxide semiconductor |
| DC | Direct current |
| ESA | European Space Agency |
| FRM4VEG | Fiducial Reference Measurements for Vegetation |
| PAR | Photosynthetically active radiation |
| PCB | Printed circuit board |
| TTL | Transistor-transistor logic |
| WMO | World Meteorological Organisation |

# Introduction

## Purpose and Scope

This document forms part of deliverable D-60 of the European Space Agency (ESA) project ‘Fiducial Reference Measurements for Vegetation (FRM4VEG)’ and it should be used as a guide to operate the Delta-T Devices BF3 Sunshine Sensor. Its purpose is to provide an instrument technical description, together with information about maintenance and calibration history, pre-deployment uncertainties estimates, and steps required to achieve the FRM status.

The document is organized into 6 key sections:

* **Section 1** provides a summary of the document.
* **Section 2** overviews the technical characteristics of the instrument together with a description of its functioning.
* **Section 3** reviews the uncertainty budget based on information provided by the manufacturer.
* **Section 4** describes all the procedures that need to be followed when using the instruments in the field.
* **Section 5** lists useful advices for care and storage of the instruments as provided by the manufacturer.
* **Section 6** lists the reasons for and solutions to common problems with the use of the sunshine sensor.

# Technical Description

## Overview

The Delta-T Devices BF3 Sunshine Sensor is a multi-purpose instrument capable of measuring incident photosynthetically active radiation (PAR). A unique shade pattern and an array of 7 cosine-corrected photodiodes enable the measurement of total and diffuse PAR without the need for shade rings, or any adjustment or repositioning of the sensor. From this, the direct PAR component can also be derived. Technical characteristics of the instrument provided by the manufacturer are detailed in Table 1.

Table 1: Technical characteristics of the Delta-T Devices BF3 Sunshine Sensor [1].

|  |  |
| --- | --- |
| **Characteristic** | **Details** |
| Overall accuracy: total | ± 10 μmol m-2 s-1 ± 12% |
| Overall accuracy: diffuse | ± 10 μmol m-2 s-1 ± 12% |
| Resolution | 0.6 μmol m-2 s-1 |
| Range | 0 μmol m-2 s-1 to 2500 μmol m-2 s-1 |
| Analogue output sensitivity | 1 mV = 1 μmol m-2 s-1 |
| Analogue output range | 0 mV to 2500 mV |
| Accuracy: sunshine hours | ± 10% compared to the World Meteorological Organisation (WMO) definition |
| Accuracy: cosine correction | ± 10% of incoming radiation over 0° to 90° zenith angle |
| Accuracy: azimuth angle | ± 5% over 360° rotation |
| Temperature coefficient | ± 0.15% per ° C typical (without thermostat) |
| Temperature range | - 20° C to 50° C with alkaline batteries- 20° C to 70° C with lithium batteries  |
| Stability | Recalibration recommended every 2 years |
| Response time | < 200 ms |
| Spectral response | 400 nm to 700 nm |
| Latitude capability | - 90° to 90° |
| Environmental: sealing | IP65 (shower and dust proof) |
| Sunshine status: contact closure (CMOS switch) mode | No sun = open circuit, sun = short circuit to ground |
| Sunshine status: logic state voltage (TTL) mode | No sun = 0 V, sun = 3.3 V (10K output impedance) |
| Internal battery | 4 x 1.5 V AA alkaline batteries |
| Input voltage range – powered from internal battery | 3.6 V to 15 V direct current (DC) |
| Input voltage range – external power | 5 V to 15 V DC |
| Logger power supply fuse | 100 mA, 24 V (self-resetting) |
| Fuse trip point, on sunshine status signal (when in switch-closure mode) | 1 A, 24 V (not self-resetting) |
| Maximum applied voltage to sunshine status output, in contact closure mode | 0 V to 24 V |
| RS232 connector | DB9 panel mounted plug |
| Signal output and power-in connector | 5 pin mini Triad 01 panel mounted plug |
| Mounting options | 1/4 “ Whitworth camera tripod socket, holes for 4 x M4 bolts at corners of box |
| Size and weight | 120 mm x 122 mm x 95 mm, 556 g |

## Theory of Operation

In order to separate the direct and diffuse components of incident PAR, two sensors are typically required: one is used to measure incident PAR from the entire sky (providing the total component), whilst another is shaded, so that incident PAR is measured from the entire sky excluding the sun (providing the diffuse component). In this approach, shading is achieved using a shade ring, which must be repositioned and adjusted to track the sun.

To eliminate the need for repositioning and adjustment, the BF3 makes use of a unique shade pattern, which consists of equal black and clear areas. As a result, all 7 of its photodiodes receive 50 % of the diffuse component of incident PAR, and one photodiode received only this. The shade pattern also ensures that at least one photodiode is always fully exposed to the sun. Using these properties, the total, direct, and diffuse components of incident PAR are calculated from the maximum and minimum of the photodiode outputs (Table 2).

Table 2: Calculation of the total, direct, and diffuse components of incident PAR from the BF3’s photodiode outputs [1].

|  |  |
| --- | --- |
| **Component** | **Calculation** |
| Total | Maximum + minimum |
| Direct | Maximum - minimum |
| Diffuse | Minimum \* 2 |

# Calibration History and Uncertainty Budget

## Uncertainty Budget

The instrument uncertainty budget was assembled by ‘Type B’ evaluation, based on information provided by the manufacturer. The uncertainty budget for total PAR is detailed in Table 3, whilst the uncertainty budget for diffuse PAR is detailed in Table 4.

Table 3: BF3 uncertainty budget for total PAR.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source** | **U value** | **Unit** | **Distribution type** | **Divisor** |
| Overall accuracy | 12 | % | Gaussian | 1 |
| Cosine correction | 10 | % |  |   |
| Azimuth angle | 5 | % | Gaussian | 1 |
| Resolution1 | 0.6 | μmol m-2 s-1 | Rectangular | 1.73205081 |
| Temperature drift2 | 0.15 | % | Gaussian | 1 |
| Total (Total) | 12 | % |   |   |
| Total k=2 (Total) | 24 | % |   |   |

1See Figure 1 for the PAR magnitude versus percentage resolution uncertainty.
2Per ° C.

Table 4: BF3 uncertainty budget for diffuse PAR.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source** | **U value** | **Unit** | **Distribution type** | **Divisor** |
| Overall accuracy | 15 | % | Gaussian | 1 |
| Cosine correction | 10 | % |  |   |
| Azimuth angle | 5 | % | Gaussian | 1 |
| Resolution1 | 0.6 | μmol m-2 s-1 | Rectangular | 1.73205081 |
| Temperature drift2 | 0.15 | % | Gaussian | 1 |
| Total (Diffuse) | 15 | % |   |   |
| Total k=2 (Diffuse) | 30 | % |   |   |



Figure 1: PAR magnitude versus percentage resolution uncertainty.

# Instrument Operation

## Instrument Setup

1. Before use, the instrument must be mounted horizontally on a tripod. A bubble level is incorporated to aid levelling.
	1. There is no need to orient the instrument in any particular direction, provided it is mounted horizontally.
2. Connect the RS232 cable to provide communication to the instrument controller.

## Performing Measurements

1. With the instrument controller on, open the SunRead software. Status information is displayed at the bottom of the window.
	1. Click the ‘Serial port’ menu and select COM port that the instrument is connected to. When communication is established, the status information will display the message ‘BF3 connected’.
2. The incident total and diffuse PAR will be displayed on screen. To log to a file, click the ‘Logging’ menu, then ‘Log to PC’.
	1. The logging window will be displayed, enabling you to select the logging and averaging periods. The most frequent logging period is 1 s, at which no averaging is available.
	2. Check the ‘individual sensors’ box to log data from all 7 photodiodes.
	3. Check the ‘log to file’ box, and then click the ‘start logging’ button. You will then be prompted to specify the file name and location in which measurements will be stored.
3. To stop logging, click the ‘stop logging’ button.

# Care and Storage

The following care and storage advice is adapted from that provided by the manufacturer [1]:

* If the instrument’s temperature is likely to exceed 50 °C, replace the alkaline batteries with 1.5 V lithium batteries. Do not use 3.6 V AA lithium batteries.
* The indicator paper inside of the should be blue. If it is pink, the desiccant requires renewal.
* The instrument’s dome must be clear and unmarked for accurate measurements. To clean it, use soapy water or isopropyl alcohol and a soft, clean cloth or paper tissue.
* Minimise the instrument’s exposure to high or rapidly changing temperatures, in so far as is practicable.
* Although the instrument is designed to resist dust and water jets (IP65), it should not be immersed in water.
* Do not drop the instrument.

# Troubleshooting

Reasons for and solutions to common problems with the BF3 are provided by the manufacturer [1], and are listed in Table 5.

Table 5: Reasons and solutions to common problems with the BF3 sunshine sensor [1].

|  |  |  |
| --- | --- | --- |
| **Problem** | **Reasons** | **Solution** |
| The instrument is not responding | A null modem cable is not being used, or the correct COM port is not selected in the SunRead software | Check cables and connections |
|  | The instrument is not receiving at least 3.6 V from its internal batteries, or 5 to 15 V DC from an external power supply | Check the battery voltage |
|  |  | The instrument’s internal microprocessor can be reset by removing and reapplying power, or by shorting pins LK4 on the main PCB. |

# Applicable and Reference Documents

[1] J. Wood and E. Potter, *User Manual for the Sunhine Sensor: Type BF3*, 1.0. Burwell, United Kingdom: Delta-T Devices, 2002.